AD-A146 736 FEASIBILITY STUDY OF THIXOGELLED FIRE EXTINGUISHANT FOR SUBMARINES(U) ENERGY AND MINERALS RESEARCH CO EXTON PA DEC 83 N00014-82-C-2238 1/1

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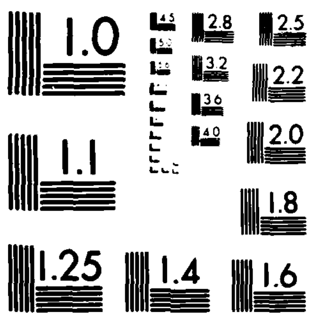

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Feasibility Study of Thixogelled Fire Extinguishant for Submarines

Final Report

under

Contract No. N00014-82-C-2238

for

United States Navy
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I. OVERVIEW

The mission of modern submarines in the fleet requires that for given periods of time they remain submerged and unexposed, even in the event of controllable onboard fires. Under submersed conditions, with the potential of exposing personnel to contaminants in the enclosed environment, the use of non-toxic fire extinguishing materials becomes imperative.

Carbon dioxide (CO_2) and potassium bicarbonate (PKP) extinguishers are now being carried on board submarines and are considered to be non-toxic materials. Neither is completely satisfactory. PKP is an effective extinguishant for flammable liquid and electrical fires, but its use is plagued by packing and caking in extinguishers; CO_2 is only marginally effective and requires flooding of a compartment or area in order to overcome a fire. Thus a single, widely applicable, adaptable and effective extinguisher would be of benefit to the Navy.

In extensive work with other fire extinguishants, E&MR has demonstrated significantly increased effectiveness over conventional systems in fire extinguishers which combine standard dry powder fire extinguishing agents, such as monoammonium phosphate, with thixotropically gelled Halon liquefied gas extinguishants. Stable, non-packing solid/liquid suspensions have been developed which result in greatly increased concentration of fire killing agents in a given canister volume. By weight also the thixotropically gelled mixture is a much more effective extinguishant. These advantages are considered to result from the fill of the inter-particle void space with an active extinguishing agent (the Halon in these cases), and the gas agent carying the non-agglomerated powder particles directly to the flame zone.

Applying the thixotropic gelling concept to a mixture of PKP and CO_2 offers the potential to provide a non-caking PKP extinguisher with

improved firekill over either PKP or CO_2, while maintaining a non-toxic extinguishant formulation.

A previous contract with the Navy (N00014-81-C-2230) demonstrated the feasibility and effectiveness of a gelled CO_2/PKP extinguishant. Present work to enable on board use of the gelled-mix extinguisher is aimed at refining the gel structure, demonstrating storage stability, and evaluating hardware modifications to ensure efficient delivery of the extinguishant.

The program has continued to demonstrate the high degree of firekill effect shown in the previous work, and in addition demonstrates a great reduction in visual obscuration and cloud formation. Evaluation of hardware variations and mix formulations was made in larger CO_2 fire extinguisher canisters (5, 10 and 15 pound capacities). A large number of different gelling materials were tested in CO_2/PKP formulations; hardware variations included dip tube size, a three finger dip tube, an agitator on the dip tubes, and nozzle configurations with opened orifices and flow paths. The results of this testing in the larger canisters were all similar; expulsion was often interrupted, yielding low expulsion efficiencies. In spite of this, panfires were routinely extinguished before interruption occurred.

A demonstration was conducted for Navy representatives near the end of the program, the results of which illustrate and summarize the benefits of the gelled CO_2/PKP extinguisher and pinpoint the areas for continued investigation.

II. FEASIBILITY STUDY OF THIXOGELLED EXTINGUISHANT FOR SUBMARINES

PROGRAM DEMONSTRATION

A. Summary

The fire extinguishing demonstration was conducted for representatives of the Navy at Energy and Minerals Research Company facilities on May 12, 1983. The objective of the demonstration was to show the state of development of the gelled CO_2/PKP extinguisher for submarines. Four carbon dioxide extinguisher cylinders containing gelled CO_2/PKP extinguishant were used on heptane panfires. Three of these were 5-pound extinguishers and one was 2-1/2 pounds. They were compared to a 5-pound CO_2 extinguisher and a 2-pound commercial PKP extinguisher. All extinguishing tests were conducted on 9-square-foot panfires.

The outstanding firekill capability of the gelled CO_2/PKP extinguishant was demonstrated by extinguishing the 9-square-foot panfire in as little as 2.2 seconds and with only 0.20 pound of PKP. Extrapolating, one pound of PKP could extinguish 45 square feet of class B fire. This time to extinguishment compares to approximately 5 and 6 seconds to extinguish the fire with a commercial PKP extinguisher and a CO_2 extinguisher, respectively. The PKP extinguished the flame using 0.63 pound of material, i.e., a rate of 14.3 square feet per pound. Three and one half pounds of CO_2 were required for extinguishment, for a rate of 2.6 square feet per pound.

Along with the excellent firekill capability, we observed that the gelled CO_2/PKP minimizes cloud formation, greatly increasing area visibility during expulsion. Cloud formation with the commercial PKP extinguisher was several times larger and more persistent than with the gelled CO_2/PKP extinguishant. This can be a significant benefit in

fighting any fire but is especially so in the confined submarine environment.

B. Experimental Specifics

The demonstration on the 9-square-foot pan was conducted outdoors using heptane as the fuel. A preburn of 45 seconds was used prior to attacking the fire with an extinguisher.

Of the four extinguishers with gelled CO_2/PKP mix, three were standard 5-pound CO_2 cylinders and the fourth was a 2-1/2 pound extinguisher. All of these extinguishers had R-51 valves as did the control CO_2 extinguisher.

The nozzle/horn configuration for two of the 5-pound cylinder (Nos. 13 and 15) and the 2-1/2 pound cylinder (No. 6) had 3/8" diameter by 3-1/2" long extension tubes with a swivel connection to allow raising of the horn. The horn was 10-3/4" long, tapering to a 2 inch diameter at the end.

The third 5-pound cylinder (No. 17) had a 1/4-inch ID 43-inch long flexible rubber hose connecting the valve and a 21-inch long horn with a 2 x 4 inch opening. This horn had a diffuser screen in the base while the diffuser tip on the valve body had been removed to provide a more direct and open flow path for the extinguishant.

Table I summarizes the data and comments of the fire extinguishing tests. Fires were extinguished in 2.2 to 5.2 seconds with the gelled CO_2/PKP units. The control extinguishers, PKP and CO_2, put the fires out in approximately 5 and 6 seconds, respectively.

The expulsion of cylinder No. 6, which extinguished the fire in 2.2 seconds, was characterized by good projection with low clouding. The discharge was stopped when the fire was extinguished and the amount of

TABLE 1

SUMMARY OF GELLED CO_2/PKP* FIRE EXTINGUISHING TESTS

Cylinder Size (lbs)	Cylinder No.	Extinguishant	Time to Extinguish Fire (sec)	Expulsion of Solids %	Comments
5	1	CO_2	6	--	Control CO_2; 3.5 lbs used to extinguish fire.
2-1/2	6	Gelled CO_2/PKP	2.2	19	Expulsion was stopped upon fire extinguishment; used 93 grams (0.20 lb) of PKP.
5	13	Gelled CO_2/PKP	3.0	33.7**	50.6% of CO_2/PKP mix expelled upon first discharge.
5	15	Gelled CO_2/PKP	4.5	99	Cylinder manually agitated during expulsion.
5	17	Gelled CO_2/PKP	5.2	38.9**	Diffusers cut from valve 1/4"-ID rubber hose (43" long) with 2" x 4" x 21"-long horn. Diffuser screen in horn.
2	--	PKP	5	32	Control PKP; 0.63 lb used to extinguish fire. Very large dust cloud.

*40/60 PKP/CO_2 ratio by weight.
**Multiple expulsion

PKP used was measured. Only 93 grams (0.20 pound) of PKP powder was used to put out the 9-square-foot panfire, a rate of 45 square feet per pound of PKP powder.

In comparison, 0.63 pound of PKP powder was used to extinguish the fire for a rate of 14.3 square feet per pound of PKP powder, three times as much powder as the gelled formulation; also in contrast, the PKP alone produced a large obscuring cloud.

The discharge of cylinders 13 and 17 was each continued after the fire was extinguished until the expulsion of powder was interrupted. Then, after a hold time of approximately 30 minutes, each cylinder was discharged a second time to maximize the PKP powder expulsion. The expulsions remained at only 33.7 and 38.9 percent, respectively, of the PKP powder, demonstrating the effect of the low mix flowability.

A demonstration of the effect of improved flow was conducted with cylinder 15, in which manual agitation was applied during discharge. In this test, where the expulsion was again continued after the fire was extinguished, 99 percent of the PKP powder was expelled without interruption.

III. RECOMMENDATIONS

A. Mix Considerations

These tests indicate that the cause of this interruption in the larger extinguishers is the low flowability of the gelled CO_2/PKP mix. Expulsions in excess of 90 percent were achieved without interruption when mix flow was promoted by agitating the extinguisher during discharge.

The occurrence of interruption regardless of the type or amount of gelant used in the mix suggests that the lack of flowability could be

based in the PKP powder. (Alternatively, it could be due to CO_2 freeze-up, as discussed below.) Discussion with a manufacturer of PKP extinguishant revealed that flow promotion additives used for standard dry powder application include silicas and clays. Both of these are commonly used as gelants in liquid systems.

Additionally, a polysiloxane coating is used on the powder to prevent agglomeration of particles during stand. Siloxanes, however, require special gelants to promote surface interactions involved in developing stable gel systems in liquids.

The implication of these findings are that the gel characteristics and flowability of the present gelled liquid CO_2/PKP mix may be dominated by the additives in the PKP powder, and that these additives are possibly incorrect in both type and quantity for system performance. The proposed approach, then, in future work is to prepare gelled liquid CO_2/PKP mixes in which the PKP powders will have one or more of the additive agents removed and only appropriate gelling agents added. This approach, along with additional modifications to ducting and valving hardware to promote flow and projection of the extinguishant, will be the primary emphasis in the proposed additional work; we anticipate that the problems described will be fully satisfied.

An alternate approach to an improved gelled mix is the use of a different liquefied gas carrier/propellant. Sulfur hexafluoride is a relatively stable compound which could be applicable. It has a liquid density of 1.37 gm/cc at 70°F, vapor pressure of 320 psig, critical temperature of 114°F and is listed in the literature as being stable in an environment of 500°C and in "red heat". The hardware for this system is likely to be similar to the CO_2 hardware and the higher density (Table II) offers the possibility of improved suspension capability. Compared to Halon 1301 (monobromotrifluoromethane) (Table

TABLE II

Stability Comparison of Liquefied Gases

	Liquid Density at 70°F (gm/cc)	Vapor Pressure (psig)	Critical Temperature (°F)	Decomposition Temperature (°C)
Sulfur Hexafluoride	1.37	320	114	> 500
Carbon Dioxide	0.75	830	87.8	---
Halon 1301	1.57	199	152.6	210

II), which in any case would not be considered for the submarine application, the sulfur hexafluoride would appear to be more stable.

B. Hardware

The consistent success with the 2-1/2 pound expulsions may be a function of the smaller size canister avoiding CO_2 freeze-up. This appears possible since difficulties are reported in expelling CO_2 alone in standard size cylinders in the field. Hardware modifications could allow freer flow.